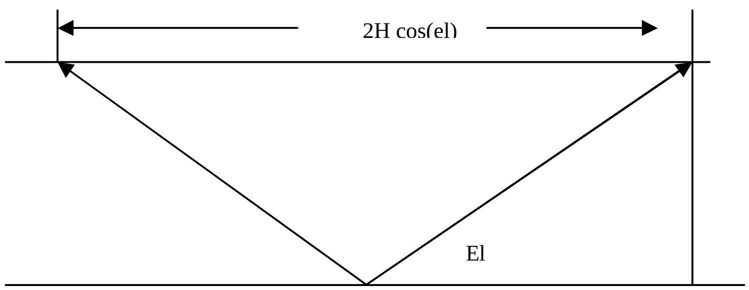
To: East Coast VLBI Workshop
From: John Gipson
Re: Azimuthal Asymmetry and Its Consequences.
Rev: October 14, 2005

The simplest model for the atmosphere in VLBI assumes azimuthal symmetry. The simplest elaboration adds gradients to this simple model. We know that the structure of the atmosphere is more complicated. In this note I present some evidence for this, and discuss consequences.

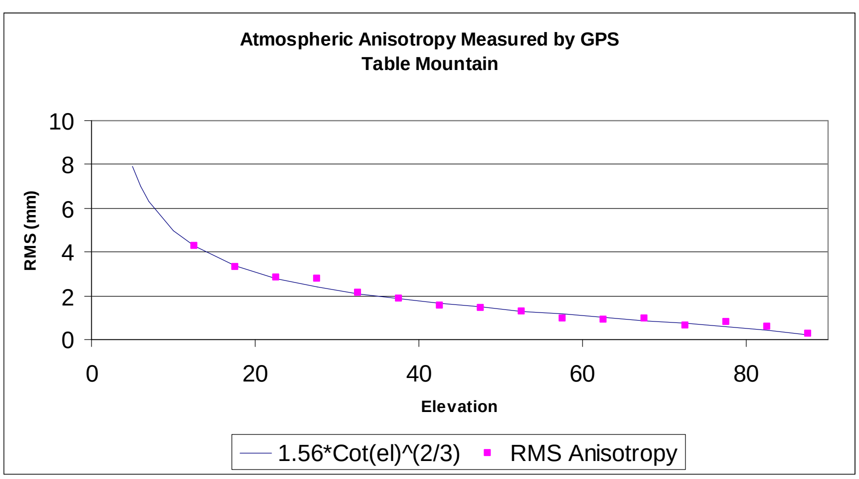
Distance Between Rays at Different Elevations

As the VLBI antenna looks in different directions the ray traverses different parts of the sky. Suppose the height of the troposphere is H. Then the distance between the ends of two rays pointing in opposite directions is 2H cos(el), as illustrated in the figure below.



Evidence of Anisotropy from GPS Measurements

John Braun, Christian Rocken, and Randolph ("Stick") Ware (Validation of Line-of-Sight Water Vapor measurements in GPS) looked at variation in GPS estimates of the atmosphere at different azimuthal angles. They binned their data in 5 degree bins, starting at 10 degrees, and going up to 90 degrees. There data is plotted in the figure below. The elevation in this chart is the average elevation of the bin.



According to Kolmorogov turbulence, the difference in the water vapor content is proportional to D^(2/3), where D is the distance between different parts of the atmosphere. From the first figure in this note, cot(el) is proportional to the average distance between the ray paths. The solid curve is the best fit line with this functional form through the data. The lowest data point is 12.5 degrees. The curve extends to 5 degrees. At 5 degrees the anisotropy is about 8 mms.

Consequences
One immediate consequence of this is that we are two conservative in our noise measurements. In particular, we need to add additional elevation dependent noise. At 5 degrees elevation the amount of noise we need to add is 27 ps.

This also has another consequence, which is that observations in the same scan are correlated. I addressed this issue in another talk.

Simulation Results
Let's look at the simplest case. Suppose that we "noise up" the VLBI observations by adding a term proportional to cot(el). What are the effects on our estimates of Up? To examine this I simulated a series of VLBI observations. To make this as realistic as possible, these simulations had the following:

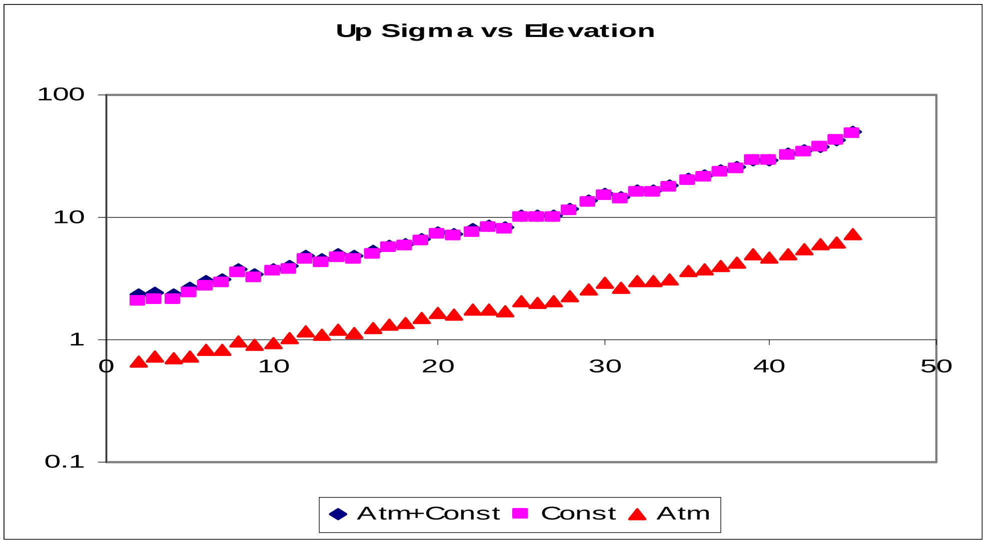
1. Observations were made uniformly above some minimum elevation angle.
2. The number of observations was 500.
3. U,E,N were estimated for the entire session.
4. Clocks and atmospheres were estimated as piece-wise linear functions.

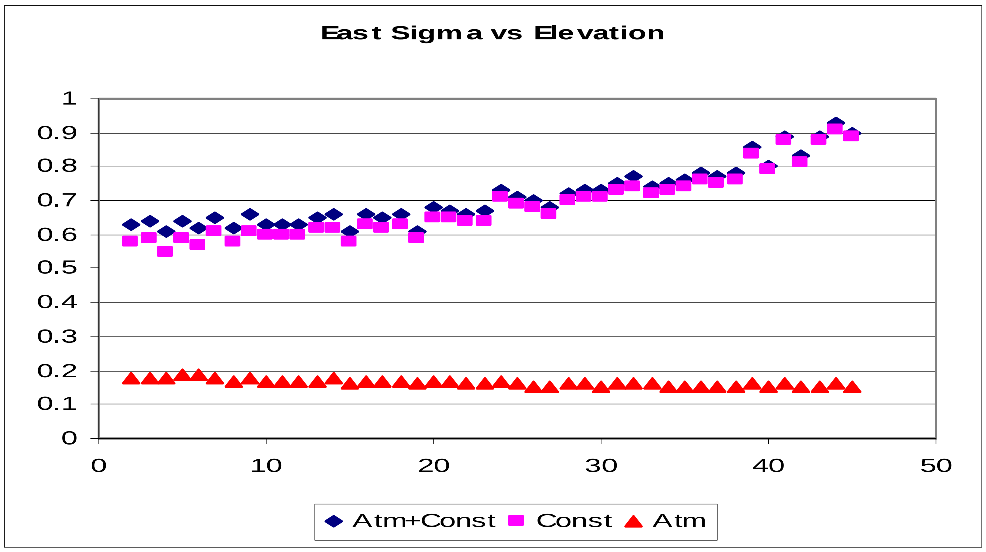
I looked 3 different cases for the noise in the observations:

1. Const. All observations have 6 mm=20 ps of error.
2. Atm. All observations have 1.56 cot(el) mm added to them.
3. Const+Atm. The noise is the sum of both.

For each case I did a series of runs where I varied the lower elevation limit. The minimum elevation was 2 degrees.

The results of these three families is presented in the figures below.





Although adding the atmosphere anisotropy correction doesn't hurt us if the noise is large (say 20 ps), it puts a floor on the uncertainty. Suppose that our measurement error is 0—this is effectively the third case. The only noise will be due to atmospheric anisotropy. In this case we find that the **minimum uncertainty in the up component is about 1 mm**, regardless of how low we go.

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